TEK INFORMATION FOR TECHNOLOGISTS

JANUARY 1981

TECHNOLOGY report

COMPANY CONFIDENTIAL

BUILDING TECHNOLOGICAL BARRIERS

VLSI

FOR GRAPHICS HARDWARE

Tektronix®
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Why TR?

Technology Report serves two purposes. Long-range, it promotes the flow of technical information among the diverse segments of the Tektronix engineering and scientific community. Short-range, it publicizes current events (new services available and notice of achievements by members of the technical community).

PAPERS AND PRESENTATIONS

While providing recognition for Tektronix engineers and scientists, the presentation of papers and the publication of papers and articles contribute to Tektronix' technological leadership image.

The table below is a list of papers published and presentations given during September 1980.

The Technology Communication Support's (TCS) Engineering Support group's charter is (1) to provide editorial and graphic assistance to Tektronix engineers and scientists for papers and articles presented or published outside Tektronix and (2) to obtain patent and confidentiality reviews as required.

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☐ Studies of Effects of Electrostatic Discharge on Solid-State Devices	Herb Zajac	—	Electrical Overstress/ Electrostatic Discharge Conference
Coatings	Gary McGuire	—	American Vacuum Society Meeting
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Data Base Systems in Electronic Design Engineering	Del Williams	—	IPAD, Denver

A box to the left of the title indicates that copies are available. For a copy of a paper or article listed here, photocopy this table, check the appropriate box, and mail to TCS, d.s. 53-077.

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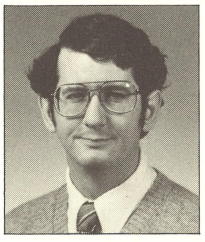
BUILDING TECHNOLOGICAL BARRIERS
VLSI FOR GRAPHICS HARDWARE



Jay Beck is a program manager in the Systems Architecture group, part of Computer Research, Tek Labs. He leads a small group that is building a special-purpose graphics processor. Prior to joining Tek in 1975, Jay was in an Air Force engineering group that supported one of the largest real-time computer-generated image-display systems for flight simulation. He has done work toward a PhD in computer science (at Purdue) and has a BS and MS in aerospace engineering.

This article is based on Jay Beck's presentation at Forum 19, *Trends in Computer Graphics.* It discusses two technologies which are usually thought of independently: color raster-scan graphics and VLSI technology. Combined, these technologies will have great impact; their potential for Tektronix is tremendous.

Raster-Scan Hardware

Color-graphics products such as the 4027 (figure 1) are, for all practical purposes, raster-scan products. Other graphic "drawing" techniques just can't handle color as easily and economically. A simple raster-scan graphics terminal can be built for "next-to-nothing" costs using readily available television hardware. Lots of people are doing it; we do it too. The use of a television-compatible raster-scan format also allows us to use components made by other divisions at Tektronix.

Raster-scan techniques permit far more flexibility than storage-tube techniques. For example, with the flexibility of raster scan, we can easily combine computer-generated imagery with a scene taken from a photograph. We can move a synthetic building around in a "real" environment (scanned-in from a photograph). However, the processing power required to generate such pictures quickly is quite large; *generating such processing power economically dictates the use of VLSI.*

To generate a color raster display we must set the color, intensity, and location of a great many pixels (picture elements). Typically, at least a quarter of a million pixels are arrayed to form a displayed image; this requires an internal data rate that is pretty high. In displaying complex interactive images in a color raster-graphics system, substantial pixel processing will result; the internal processing rates can reach as high as 70 megahertz.

To provide increased display power to our customers, we will have to place more emphasis on the design of the display processor. To strengthen and protect our market position, we must develop proprietary display-processor systems rather than depend on a single proprietary device such as the direct-view storage tube. These system designs will build technological barriers for our competition.

Figure 1. The 4027 Color Graphics Terminal offers the customer the ability to use up to eight colors simultaneously; these colors are selected from a 64-color "palette." Local capabilities include color vectors, characters, symbols, and polygon fill. The 4027 is the first Tektronix color raster-scan graphics product.

Designing With VLSI

The design considerations for a graphics processor are no different than for any other product:

- Do I have the right problem?
- Do I have the right tools?
- Will my solution be the correct one?
- What's the potential payback to Tektronix?

To help you answer these questions, consider that products using VLSI should have these characteristics: high volume, high-performance-to-price-ratio, and high ratio of internal circuits to the number of input and output signals (in other words, high gate counts, low pin counts). In addition, when considering a product for VLSI, it is essential that it be well-planned, well-designed, and well-documented.

Powerful computer aids and standardized new IC processing techniques are emerging that will allow IC design to be simplified; the design of special-purpose systems such as display processors can become a routine engineering task. With these emerging developments, we can reduce custom IC costs significantly where:

- there are a lot of elements per package and
- Tektronix can mass produce them to achieve low cost.

Carver Mead and Lynn Conway have done significant work in this field and we are studying their proposals. Mead is head

GLOSSARY

Machine – Computation system.

Pixel – Acronym for picture element. The smallest area of a television picture capable of being delineated by an electric signal. In addition to color and intensity information, it has three important properties: the vertical height of the picture element, the horizontal length of the picture element, the aspect ratio of the picture element. In addition, the total number of picture elements in a complete picture is of interest since this number provides a convenient way of comparing systems.

Raster Scan – A method of sweeping a cathode-ray-tube screen characterized by a network of parallel sweeps either from side to side or from top to bottom.

Tiler – A processor that generates picture-element values based on higher-level image-description primitives such as polygons.

of the Silicon Structures Program at the California Institute of Technology. Conway manages LSI Systems at the XEROX Palo Alto Research Center.

VLSI, then, can be economical and effective for graphic products. Presently, each VLSI package is costly in absolute terms, but this problem is being addressed by Tek CAD/CAM activities. So, at this point I'd like to talk about the most effective use of VLSI.

Building the Technological Barrier

Special-purpose applications maximize VLSI advantages. If you choose the right application for VLSI, you can build a formidable technology barrier that any competitor will find hard to breach. For example, where competitors build cheap color-graphics terminals by simply adding a large slice of memory and some firmware, with proprietary VLSI, we can do much more. We can provide significantly more capability by providing many features and high potential for interactive use. And we can provide this capability at a reasonable price. Very few competitors can just go off and build chips like we must be able to do. And . . . *we've had years of experience with graphics, experience that few competitors can claim.*

We can establish technology barriers by:

- Matching the processing power of the chip to the design goals we have set for the graphics product.
- Avoiding sequential processing. We must break the strong hold that conventional machine architecture has on our thinking. We must solve problems with *concurrent processing,* that is, getting that picture on the screen quickly by processing information simultaneously.
- *Take systems connections off the supporting elements and put them into the IC.*

Communication is expensive and computation is cheap; we know that but often are not guided by this principle. Etched-circuit boards, runs on the boards, and motherboards don't do anything but support those parts that are doing something. It's the communication between those parts through the supporting elements that is really expensive; those little parts, the ICs that do the work, are cheap. Take those system connections off the supporting elements and put them into an IC and you increase system reliability, decrease power consumption, and significantly reduce communication expense. *Economy is achieved in silicon.*

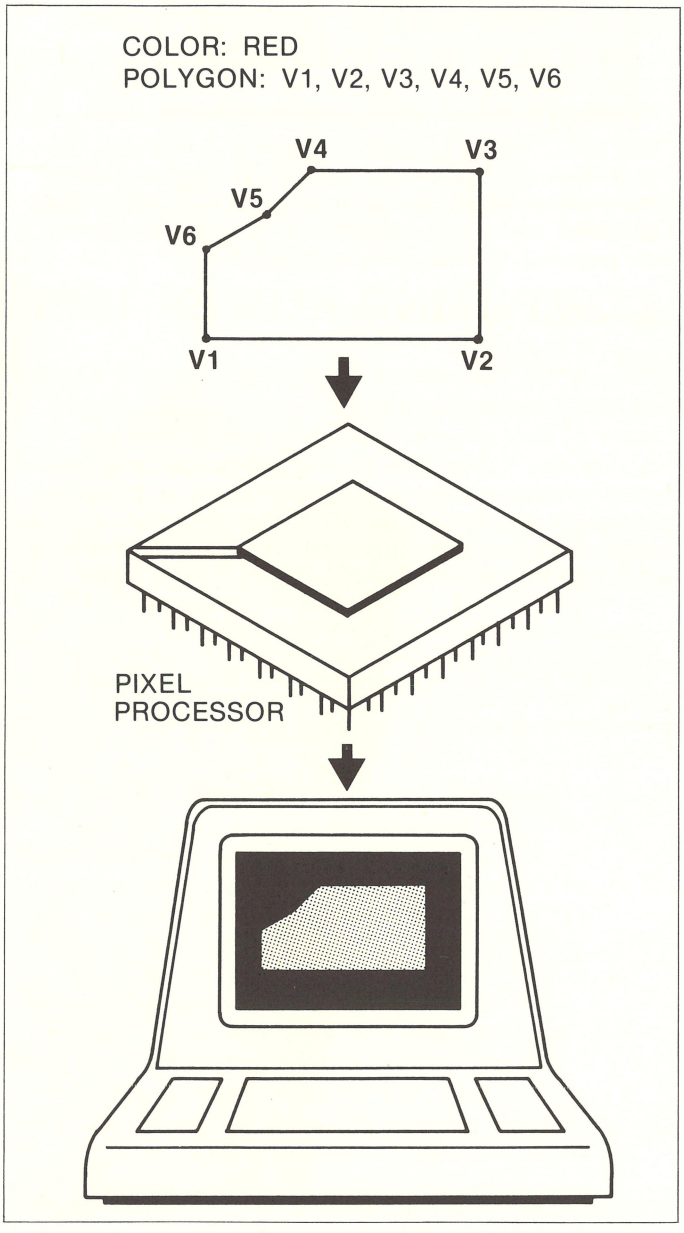
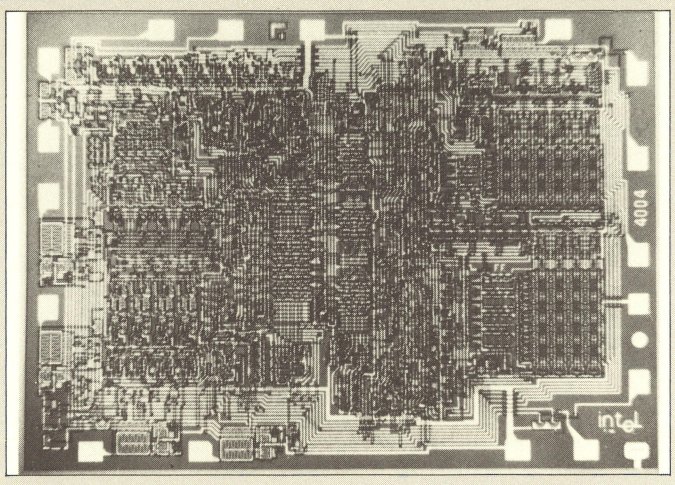


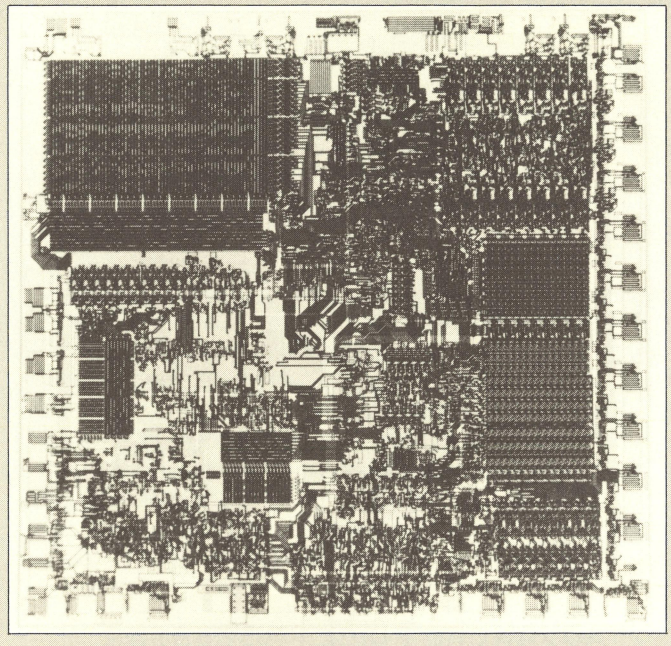
Figure 2. This advanced pixel processor processes figure definitions, in this case a polygon, in order to quickly format the figure data for raster-scan display.



The 4004 microprocessor is only 150 × 111 mils in size. The now "primitive" 4004 packs approximately the same computing power as the 30-ton ENIAC built in 1949.

COMPUTING POWER 1949 to 1981

The now primitive Intel 4004 microprocessor is an early example of VLSI technology. It has 1200 transistors on a 150 × 111 mil chip. In performance, the 4004 compares very favorably with the first digital computer, the ENIAC, introduced in 1949. The enormous ENIAC and the tiny 4004 are almost equivalent in computing power. But the 4004 is twenty times faster than the 30-ton ENIAC which required 18,000 vacuum tubes sweating to achieve 100,000 instructions-per-second. The instruction cycle time of the 4004 is 10.8 microseconds with about 60 instructions.



The 8086 microprocessor which, at 225 × 225 mils, is just a bit larger than the 4004, but it's about fifty times faster.

In just a few years, technology has leaped from the 4004 to the 8086. Somewhat larger than the 4004 (225 × 225 mils), the 8086 has 29,000 transistors and a cycle time of 200 nanoseconds, much faster than the 10.8 microseconds required by the 4004.

Soon, we will be working with ICs having over a million transistor equivalents on larger chips. Because of the promise of this technology, I expect our graphics hardware will be ***VLSI hardware.***

Computer-aided design can keep VLSI costs in hand by using predefined silicon structures having standardized components. Let's not start at ground level to fabricate everything. Let's start with predefined silicon structures and then add layers to fit applications, prefabricated gate arrays on wafers, for example. Or we could use a software approach with archived hardware designs and CAD tools to build systems. Let's relax our design constraint that makes us try to get as much as possible on a piece of silicon. This constraint wastes engineering effort because we have to reoptimize everything every time someone comes up with a change. It would be better to "waste" a little silicon in order to gain productivity and economic efficiency.

When you use predefined silicon structures, you will find that the structures that are best applicable to VLSI are based on algorithms that use only a few different types of cells. In other words, a few types of components doing a few different tasks. We don't want a lot of discrete circuitry that has to be changed into VLSI because of a poorly chosen application algorithm.

By choosing the right algorithm, *using only a few different cells,* it will be easy to have a *regular interconnection scheme* between those cells. Then, our design will be *modular,* because we won't be using many types of components. Also, we want to make the design suitable for *concurrent execution* (parallel processing). Most algorithms that satisfy these first criteria tend to satisfy this last one.

A Pixel Processor

Let's discuss a potential application for VLSI, a pixel processor for very high-resolution displays (figure 2) whose job is to take a representation of a figure, such as a polygon, which is defined in terms of vertexes and color, and pass it through special-purpose hardware (built with VSLI technology) to quickly get the representation on screen.

To design this pixel processor we will exploit some of the features I've talked about. We'll build a chip that contains a binary tree of processors. Each one of the squares in the "trees" might require something as simple as the 4004 or as complex as the 8086. (See inset: *Computing Power 1949 to*

1981) The tree of processors is laid out on the die to form an integrated silicon system. In figure 3, you see the types of processors, each designed for a specific job. Splitters separate the polygon information down to progressively lower-level processors until we get to the end of the tree where tilers scan-convert horizontal "slices" on the polygon into pixels. (These "slices" are called scan lines.) Each tiler serves a dedicated part of the total memory used to create the entire display.

Let's go back, then, to those predefined silicon structures and relate them to a specific example, as in figure 3. We can see that the algorithms are implemented with two cell types.The data flow is simple, very regular, and the cells are interconnected on silicon. In this pixel processor, we have an extensive use of parallelism because the tree is binary and every time you drop one level of the tree you double the computational elements. So, as data comes in, it is divided and routed to more and more processing elements that work simultaneously; as a result you have several data streams flowing simultaneously between processors on the chip. Many cells are active at one time; therefore, data rates are extremely high even though the computation speed of individual processors may be slow (if we are using MOS technology as opposed to a higher-speed technology such as bipolar). Because we have multiple machines working concurrently on the job, we achieve the desired high computational rate.

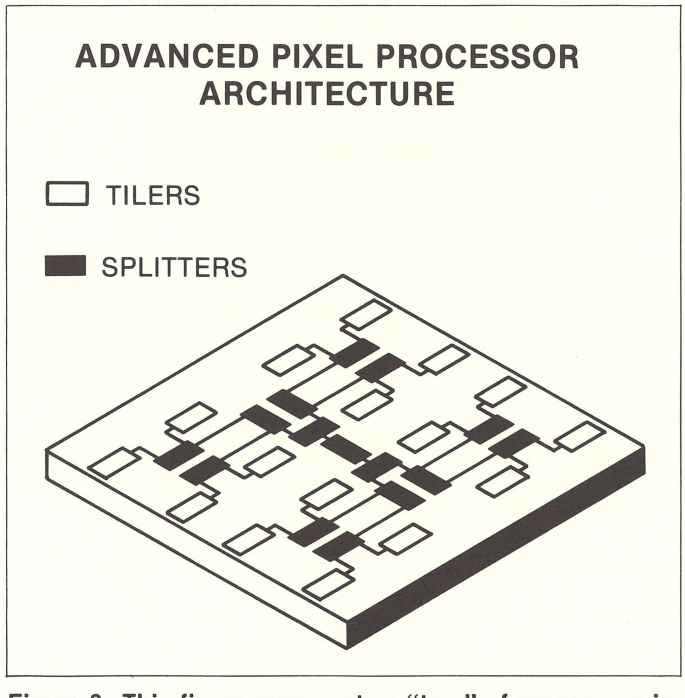


Figure 3. This figure represents a "tree" of processors in a VLSI die that has *just two different cells,* has a *regular interconnection scheme,* and is *modular.* This design is suitable for *concurrent execution.*

COLOR COMMUNICATES

Color, or more exactly a variety of colors, boosts the communication power of a CRT display impressively. It can be used to "flag" a malfunctioning valve in an on-line display of a chemical plant monitoring system. In complex displays, it enhances the readability of data. It adds realism to modeling displays with shadow, reflection, refraction, and transparency effects that make the model more real, or more abstract. In mechanical-engineering applications, color can reveal the concentrations of stress. In computer-aided design, color graphics are finding fascinating applications in both printed circuit and IC layout.

Conclusion

In the 1970s we saw the advent of microprocessors. In the 1980s we will see heavy use of VLSI custom-tailored for a specific application. With VLSI hardware customized for color raster-graphics applications, we can employ substantial hardware parallelism without increasing costs and we will sustain the trend toward more productive features and more interactivity.

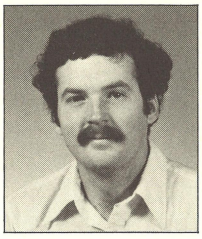
I'd like to propose a new phrase, *cost-performance-effective hardware.* Not just cost-effective hardware, but cost-performance-effective hardware — doing the job best, for the most effective price.

Custom-tailored VLSI graphics processors must become part of Tek proprietary hardware. Such use of proprietary VLSI will create the technology barrier our competitors must face; it will also serve our customers' needs.

For More Information

For more information call Jay Beck, ext. B-7856. □

A NEW THERMAL-IMAGING SYSTEM



Ken Smith is an engineer in the Packaging Department of Hybrid Circuits Engineering. After summer-interning in 1978 and 1979, Ken joined Tek full time in November, 1979. He is completing his work toward a general engineering degree from Oregon State University through classes held on Tek's "campus."

Background

The thermal characteristics of a semiconductor device often critically affect its electrical performance. For this reason new Tektronix devices are subjected to analytical thermal modeling during the layout phase. Hybrid Circuits Engineering (HCE) has several computer programs which predict the device operating temperatures, given the power dissipation and heat-sinking condition. By using these programs, engineers can thermally optimize a design before the prototype device is built.

It is after the device is built that the Thermal-Imaging System has proven the most valuable. Prior to the development of the system, the methods available for measuring device operating temperatures consisted of attaching a thermocouple to a specific component, junction-pulsing a particular transistor, or performing an infrared spot measurement. Although these methods are reliable and accurate, they are inherently single-spot measurements. Complex devices such as multichip hybrids and large-scale integrated circuits require high-resolution temperature data from relatively large amounts of surface area. The Thermal-Imaging System was developed to meet this need.

The New Thermal-Imaging System

The new Thermal-Imaging System produces top-surface thermal maps of integrated circuits and hybrids using non-contact infrared-emission techniques. With the system, components are tested in their production packages (without lids). Data is presented to the user in the form of an isothermal contour map which can be directly compared to the integrated-circuit overlay or the hybrid layout.

The main components of the Infrared Thermal-Imaging System are: a Tek 4051 Graphic Computer System, a modified Tek 4662 Interactive Digital Plotter, a precision x-y table, and an infrared radiometric microscope (see figure 1).

With the Infrared Thermal-Imaging System, a typical scan is made in the following manner. The device under test is mounted on the x-y table, powered up, and allowed to reach thermal steady-state (constant temperature). Then the area to be scanned is located and registered in the 4051. Next the temperature of the first data point is measured by the microscope and the analog value is transmitted to an infrared meter whose output drives an analog-to-digital converter. The digitized data is stored by the 4051, completing the first measurement. The 4051 then drives the x-y table to the next data point where another measurement is made. The system follows a serpentine pattern over the entire scan area until the temperature of each discrete point has been registered.

After all the temperature measurements are recorded, the 4051 plots isotherms (lines of constant temperature) and prints a hard copy. This plot can then be referenced to a hybrid layout,

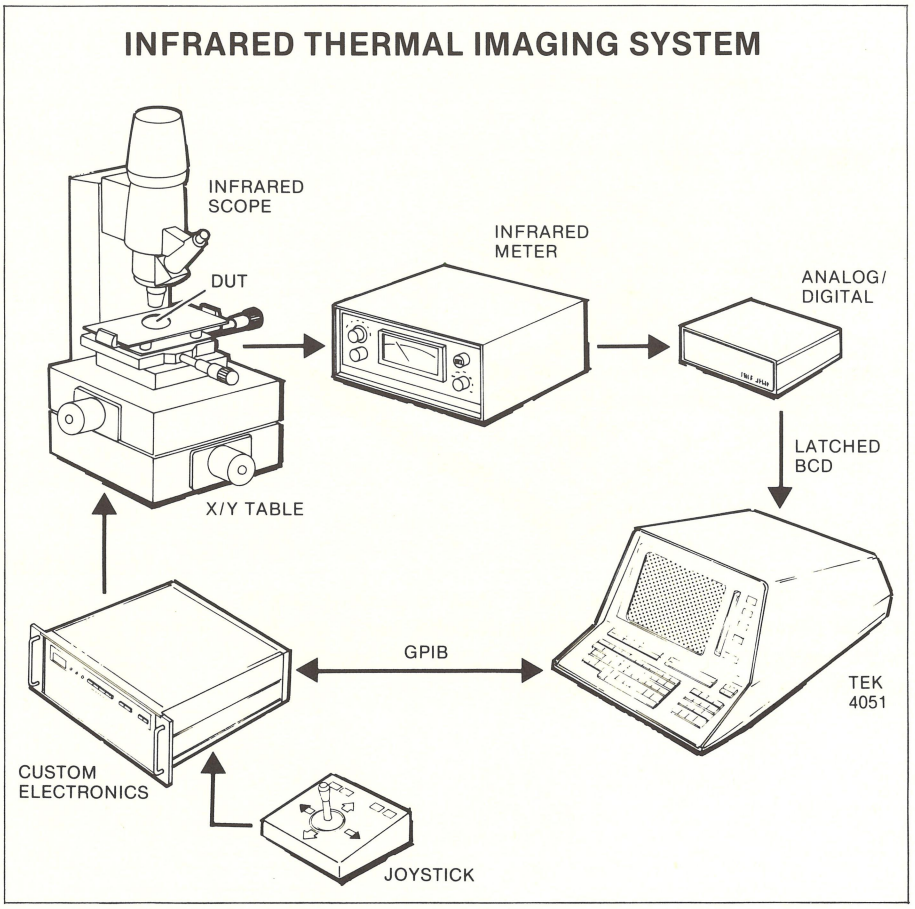


Figure 1. A diagram of the new Thermal-Imaging System. This system provides high-resolution temperature data for devices such as multichip hybrids and large-scale integrated circuits. The device under test (DUT) is positioned by the system to make measurements at many precisely defined points on the device's surface.

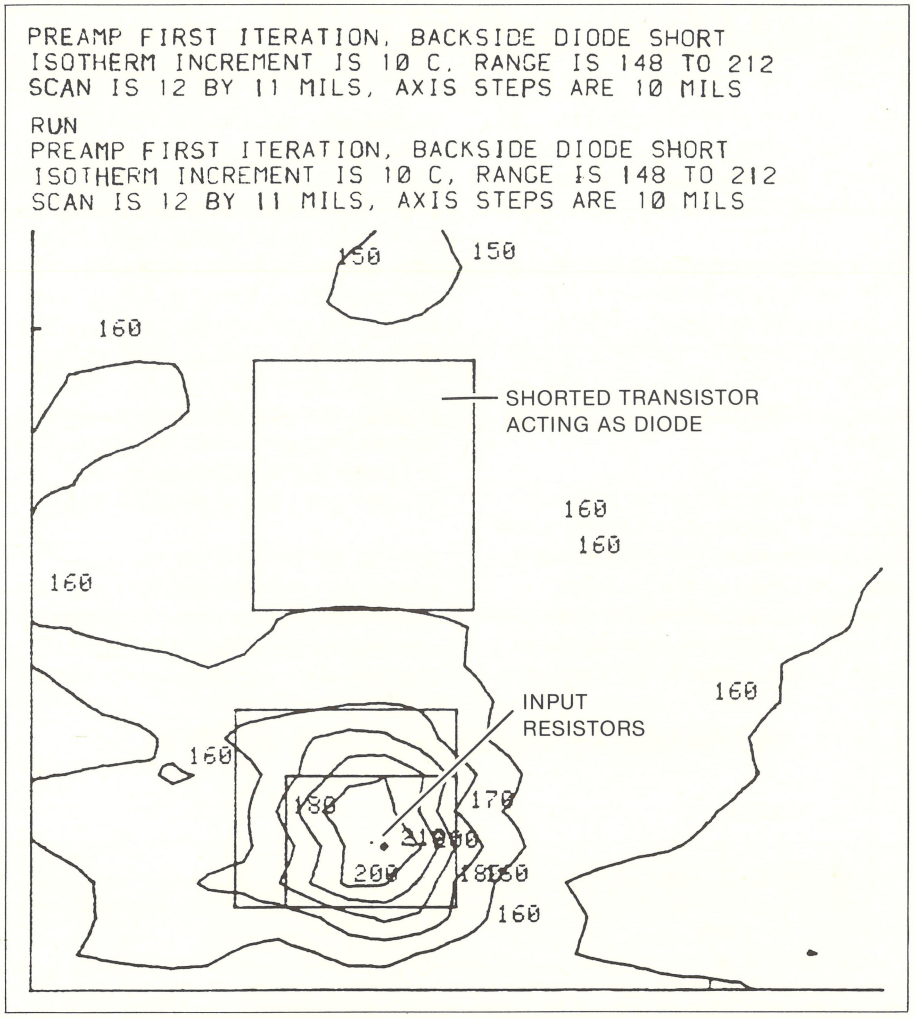


Figure 2. This plot reveals a "current-hogging" (shorted) transistor (upper rectangle) which is causing its input resistors to run very hot (200 degrees C). This scan focuses on a very small area (11 by 12 mils) of a large-scale integrated circuit.

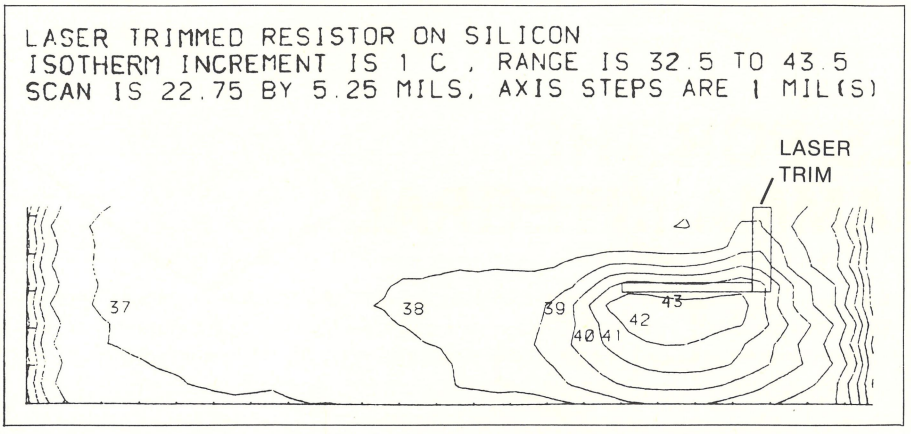


Figure 3. This plot reveals a hot spot (43 degrees C) on a laser-trimmed resistor. The localized current crowding is caused by the trim cut. Results, such as these, can be used to optimize trimming techniques.

or a top-metal overlay, to determine the actual operating temperature of various junctions and resistors.

Test Examples

The plots in figures 2, 3, 4, and 5 illustrate the type of information obtained with this system. As can be seen, the system's primary attributes are its extremely high resolution and the ability to present a very large amount of data in a usable format.

We have used the system to locate a "current-hogging" transistor on a new integrated circuit (figure 2), identify localized extreme heating on laser-trimmed resistors (figure 3), and study materials for new large-scale-integration hybrids (figure 4). In one case we determined the thermal gradient across the data matrix of a charge-coupled device to be within less than two degrees Celsius (figure 5), which was within perform-ance requirements of the device.

We Encourage You to Use the System

Because the system yields so much useful data, we encourage you to use it. You will find the process of testing to be relatively easy and inexpensive.

To use the system, this is what you do:

1. Provide at least one device; however, it's better to test three or four devices so we can correlate results. We will passivate devices with silicon nitride and paint them with a black Aqua-Dag in order to insure constant emissivity over the entire surface. You should tell us the heat sinking scheme to be used.

2. Provide a "burn-in" circuit (or schematic) to power the device. Please provide:
- a method to determine whether the device is working properly,
- the total power dissipated by the device, and
- specification of external heat sources (such as resistor networks).

Note: If you provide the circuit, we can give you faster turnaround. We do have power supplies, but our clock and signal inputs are limited.

3. Provide an overlay set (or copy of one) for our visual reference. On the overlay you should:
- mark areas of special interest to be scanned at peak resolution (such as critical transistors) and
- note areas to be registered and superimposed on the thermal map.

4. For further information, contact Ken Smith, ext. B-6098.

The Previous Methods

The Thermal-Imaging System is based on the infrared spot method. This method and the junction-pulse method are explained here to help you better understand the use and the advantages of the Thermal-Imaging System.

Infrared Spot Method

This method uses the Barnes RM2A Infrared Radiometric Microscope, a temperature-measuring instrument. It can be focused on a 1.2 mil spot and, by collecting the infrared radiation emitted from that spot can determine the temperature of the spot. The data interpretation is quite complex because the amount of radiation emitted from an object depends on both its temperature and its emissivity. Emissivity, the power to radiate heat, is an intrinsic property of materials. There are a wide range of values for the various metals found in semiconductor devices. Therefore, emissivity must be compensated for when making temperature measurements.

Continued on page 11

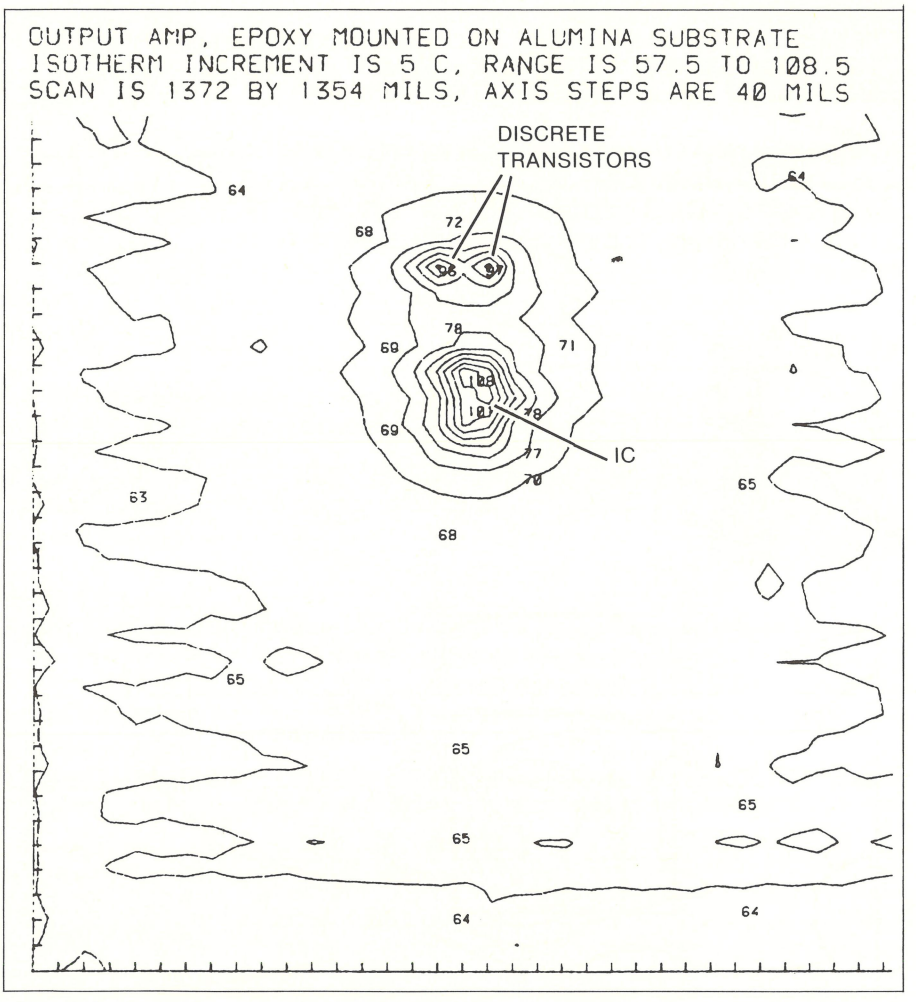

OUTPUT AMP, EPOXY MOUNTED ON ALUMINA SUBSTRATE
ISOTHERM INCREMENT IS 5 C, RANGE IS 57.5 TO 108.5
SCAN IS 1372 BY 1354 MILS, AXIS STEPS ARE 40 MILS
DISCRETE TRANSISTORS
IC

Figure 4. This plot of a large hybrid (1.3 by 1.3 inches) was made as part of a materials study. In this study, scans were made of several hybrids employing different die attach methods and substrate materials. The study showed the epoxy mount on alumina substrate to be satisfactory for the particular application considered.

A SIMPLE SERIES FOR THE INCOMPLETE GAMMA INTEGRAL

Andy Lau's paper "A Simple Series for the Incomplete Gamma Integral" has been published in the Royal Statistical Society's **Applied Statistics.** Andy Lau is a software engineer in Applications Engineering, part of Graphic Computer Systems.

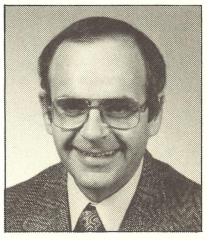
The incomplete gamma integral and the incomplete beta integral are very important functions which are widely used in statistics. Andy's paper presents an algorithm for evaluating the incomplete gamma integral. His algorithm (designated AS 147 by the Royal Statistical Society) is different from the previously published algorithm AS 32 that considers separate cases and employs continued fraction approximation. In AS 147 there is only one case; thus AS 147 substantially reduces programming without sacrificing accuracy.

For further information, call Andy Lau W1-3551.□

ENGINEER V PROFILE

ARNOLD FRISCH

Engineer/Scientist IVs and Vs serve as technical resources both inside and outside the company. To increase their visibility to the Tektronix technical community, *Technology Report* is publishing a series of profiles of these individuals.



Arnold Frisch, Applied Research, ext. B-5611

In a talk to new-hires, Arnie described himself as "a survivor and a prosperer in the battle against personal technical obsolescence." He has kept pace with fast-moving technology ever since his first employment in electronics in 1957.

Today, Arnie, far from being obsolete, develops new techniques and circuits for signal processing. Working in the Applied Research group (part of Tek Labs), his recent areas of concentration include a pipelined analog-to-digital converter and several high-performance integrated circuits. Pipelining is the act of parceling out a processing task so that it is accomplished sequentially with the results of each of the subprocesses simultaneously communicated to the beginning of the next subprocessing level. Thus, a complete task takes some number of clock cycles of delay, but a new task can be handled at each clock cycle.

Over the years, ten patents bearing Arnie's name have been granted; two more are in the disclosure state. His papers and reports range over subjects as diverse as lead-acid batteries, radio-frequency interference, and impulse generators. He recently completed two reports: "Histogram Construction for Performance Analyzer" and "Data Compression Techniques for Logic Analyzers."

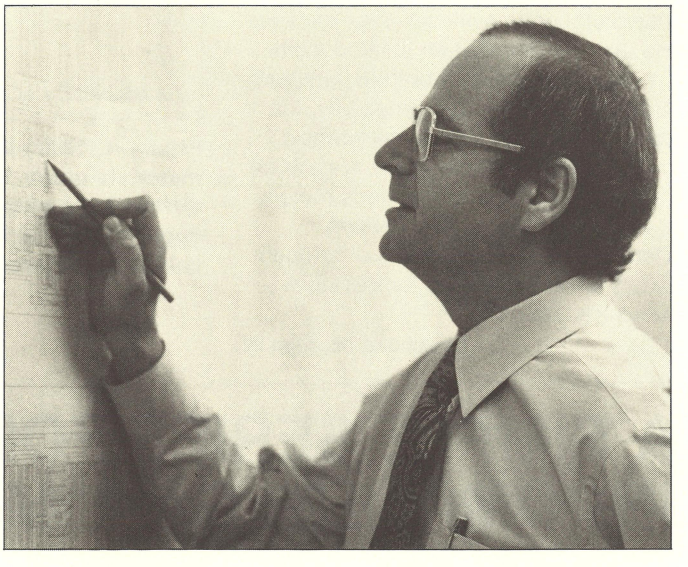
Arnie's first employment in technology was with Polarad Electronics where his work included assignments as varied as circuit design to government-contract liaison. At that time, 1957, Polarad was a leader in electronic counter measures . . . they were also a major source of *spectrum analyzers.* It was a spectrum analyzer that brought Arnie to Tek.

In 1962, Arnie and two associates, Morris Engelson and Larry Weiss, left Polarad to form a company to build spectrum analyzers that were *plug-in* compatible with Tektronix 530/540 Series Oscilloscopes. The Pentrix effort was successful and attracted customer and Tek attention. In 1964, the founders of Pentrix sold their company to Tek and moved to Beaverton with the prototypes of several analyzers, one of which was to become the 491. The 491 was the first portable analyzer in an era when analyzers were heavy-weights, often weighing over 100 pounds. The 491 was successful; over the years it won substantial orders until it was replaced in 1980 with the 492 Spectrum Analyzer.

After seven years at Tek, where his assignment was managing Tek's Spectrum Analyzer group, Arnie left in 1971 to become chief engineer of Elektros, Inc., developers of an electrostatic electron microscope. More recently he was chief engineer of Zygo, a company pioneering in communication aids for severely disabled individuals.

Maintaining his association with Tek (as a consultant), Arnie contributed to logic-analyzer and signal-processing techniques. He rejoined Tek in February 1980.

Arnie would be happy to discuss your problems in high-speed analog or digital circuits and the signal processing field. Or perhaps you would like to discuss the personal challenge to keeping up technologically. □



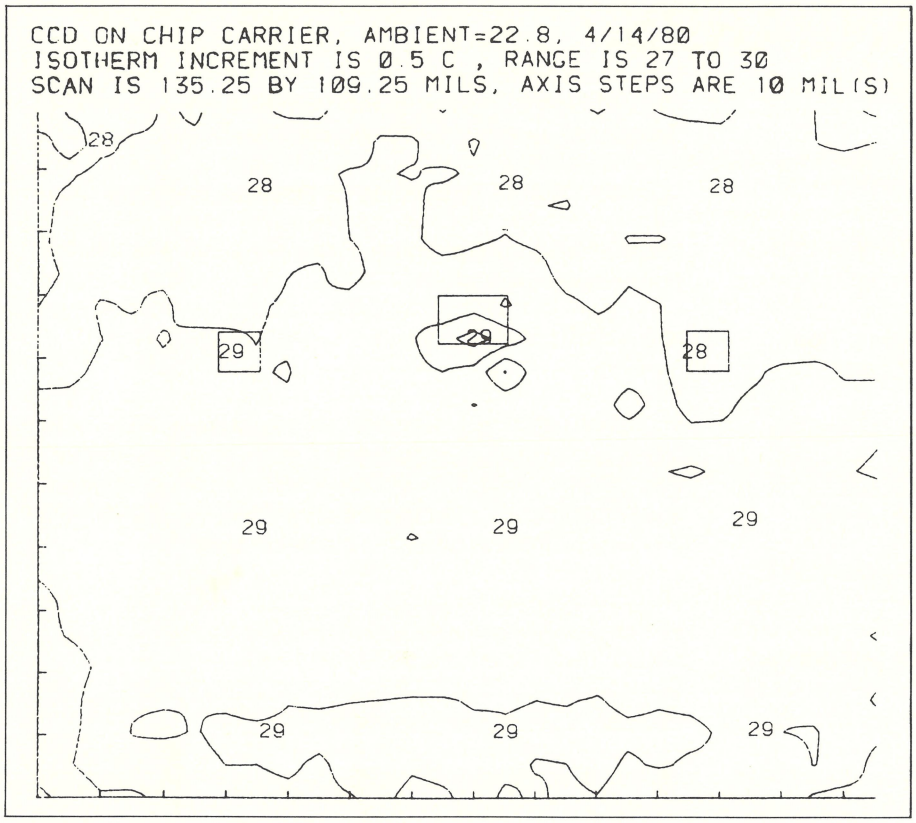


Figure 5. This plot shows a charge-coupled device having the desired temperature gradient. The entire device operates within the 27 to 30 degree C range. This was well within specifications.

Thermal Imaging continued

The easiest and most accurate way to compensate for emissivity is to coat the entire device with a constant-emissivity coating — in essence, paint it black. We use a very thin coating of carbon black to make the device under test a blackbody emitter. But the device must first be electrically passivated with an insulative surface coat in order to prevent the conductive carbon from shorting it out.

This black coating has one major drawback; it makes it difficult to identify what the microscope is looking at. We can determine a temperature, but not the location. However, the infrared-spot technique is still useful for some applications, such as measuring a single hot spot over the junction of a discrete transistor. We simply find the hottest spot with the microscope and assume it's the junction. Results of these measurements correlate quite well with the junction-pulse technique.

The Junction-Pulse Method

In the junction-pulse technique, a source current, set for the desired power level, drives a transistor for 99.9% of a duty cycle. For the remaining 0.1% of the cycle, the base-emitter junction is pulsed with a sense current (typically one milliamp) and the base-emitter voltage is measured during the pulse. Because the base-emitter voltage varies almost linearly with temperature, the temperature of the junction can be determined from this voltage. (The relationship of temperature and base-emitter voltage is calibrated in an oven at the sense-current level.) This method works very well on discrete transistors.

For More Information

For more information, call Ken Smith, ext. B-6098. □

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MIL-S-46163 — Sealing, Lubricating, and Wicking **Compounds:** Thread-Locking, Anaerobic, Single-Component.

MIL-STD-45662 A — **Calibration** Systems Requirements.

Fed-Spec QQ-R-566B — Federal Specification Rods and Electrodes, **Welding** Aluminum and Aluminum Alloys.

MIL-I-28947A — Illustrations for **Technical Repair Parts** Publications: Preparation of.

MIL-F-55561B — Foil, Copper, Cladding for **Printed Wiring Boards.**

MIL-P-46112B — **Plastic Sheet and Strip,** Polymide.

MIL-M-7298C — **Manuals, Technical:** Commercial Equipment.

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MIL-W-47192(MI) — Amendment 1 — **Welding** Rod and Wire, Nickel Alloy High Permeability Shielding Grade.

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MIL-STD-1353B — **Electrical Connectors,** Plug-In Sockets and Associated Hardware, Selection and Use of.

MIL-STD-199B — **Resistors,** Selection and Use of — Notice 6.

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